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Decision-Making for Project Delivery System in Construction Projects Based on SWARA-TOPSIS Methods

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Keywords:
Construction Management; Decision-Making; Project Delivery Systems; SWARA; TOPSIS.

Highlights:

- *Construct a method for project delivery decisions and provide a reference for the owner to select the proper project delivery system.*
- *Combined methodology of (SWARA) and (TOPSIS) are proposed for project delivery system selection.*
- *The most significant factors affecting the decision about the project delivery system are determined.*
- *To determine the factors' weights, the SWARA method is used and the TOPSIS technique determines the rank of the alternatives proposed for the delivery system.*

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Abstract: The owner of construction projects often faces difficulty choosing the appropriate project delivery system. The construction project's owner must choose a suitable project delivery system throughout the project's early decision-making stages. This choice greatly impacts the success of the project. This paper aims to construct a method for project delivery decisions. This method can provide a reference for the owner to select the proper project delivery system. This research described the factors affecting the decision about the project delivery method through a literature review. These factors were categorized into eight groups: scope, time, quality, cost, risk and relationships, owner organization, project characteristics, and external environmental factors. Then, a combined methodology of Stepwise Weight Assessment Ratio Analysis (SWARA) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are proposed for project delivery system selection. The SWARA is used to determine the factors' weights. The TOPSIS technique determines the rank of the alternatives proposed for the delivery system in the various categories. The results showed the most significant factors related to the cost with a weight of 0.335, and the design-build is the closest to the ideal solution and ranked first among the other suggested project delivery systems with a relative closeness of 0.829. This paper stipulates the basis for such a process of decision-making.

اتخاذ القرار لنظام تسليم المشروع في المشاريع الانشائية بالاعتماد على طرق SWARA-TOPSIS

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الخلاصة:

يواجه صاحب العمل في كثير من الاحيان صعوبة في اختيار نظام التسليم المناسب للمشروع. من الضروري أن يختار صاحب العمل نظامًا مناسبًا لتسليم المشروع خلال مراحل اتخاذ القرار المبكرة. ان نجاح المشروع يتأثر بشكل كبير بهذا الاختيار. ان الغرض من هذه الدراسة هو بناء طريقة لاتخاذ قرار تسليم المشروع. يمكن أن توفر هذه الطريقة مرجعًا لصاحب العمل لتحديد نظام التنفيذ الملائم لمشاريعه. تم في هذا البحث وصف العوامل التي تؤثر على اتخاذ القرار بشأن طريقة تسليم المشروع من خلال مراجعة الأدبيات. حيث تم تصنيف هذه العوامل إلى ثمانية مجموعات: النطاق والوقت والجودة والتكلفة والمخاطر والعلاقات وتنظيم المالك وخصائص المشروع والعوامل البيئية الخارجية. ثم تم اقتراح منهجية مشتركة لتحليل نسبة تقييم الوزن التدريجي(SWARA) وتقنية ترتيب التفضيل عن طريق التشابه مع الحل المثالي (TOPSIS) لاختيار نظام تسليم المشروع حيث ان طريقة SWARA تستخدم لمعرفة أوزان العوامل بينما تستخدم طريقة TOPSIS لمعرفة مرتبة البدائل المقترحة لنظام التسليم بين الفئات المختلفة. اظهرت النتائج ان أهم العوامل تتعلق بالتكلفة وبوزن 0,335 وان النظام تصميم-تنفيذ هو الأقرب إلى الحل المثالي ويحتل المرتبة الأولى بين أنظمة تنفيذ المشروع الأخرى المقترحة وبتقارب نسبي 0,829. توفر هذه الورقة البحثية اساس لمثل هكذا عمليات لاتخاذ قرار.

الكلمات الدالة: نظم تنفيذ المشروع، SWARA، TOPSIS، إدارة الانشاء، صنع القرار.

1.INTRODUCTION

Project participants' rights and obligations are established by the project delivery system (PDS) and project contract management, speed of construction, cost, and quality, all of which are essential to a project's success [1]. Over the past several decades, the construction sector has sought efficient project delivery systems to maximize performance [2]. Construction projects can use various project delivery systems. There are alternatives for project delivery strategies, such as design-build (DB) and build-operate-transfer (BOT), in addition to the standard design-bid-build project delivery method (DBB). No specific project delivery method is most suitable for any project type. Instead, many solutions are combined for various situations [3]. Choosing an appropriate PDS is a difficult decision considering many factors. Scholars have extensively studied the various factors affecting PDS selection. Therefore, the factors that influence the PDS selection have already been determined. However, because so many elements cannot be valued equally, the clients still have difficulty deciding which factor should be prioritized. Consequently, there is an urgent need for significant and efficient examination factors impacting PDS selection to assist the clients in making that decision [4]. In recent years, several academics have concentrated on Multiple Criteria Decision-Making (MCDM) models for making difficult decisions under various factors. This concept is frequently applied when a particular issue involves several distinct properties, including quantitative and qualitative ones, at the same time, such as cost, significance, capacity, and lifetime [5,6]. The factors affecting the selection of PDS have been extensively studied. Eight categories of factors are identified from examining previous works: characteristics and requirements of client, characteristics of project, and external environment. Additionally, selecting a PDS is impacted by several criteria listed in Table 1.

Table 1 Factors Affecting the Decision-Making of Project Delivery Systems.

No.	Categories	Descriptions	Literature Source
1	Time-Related Factors	This category ensures the entire design and construction process is completed quickly and on schedule.	[7,8]
2	Cost-Related Factors	This category comprises ensuring the project is completed within budget and at the lowest possible cost, payment method and payment schedule, the need for financing, minimizing expenditure, and the desire for early estimates.	[7-9]
3	Scope-Related Factors	The clarity of the project scope can affect the decision to select a project delivery system, making the most of a clearly defined scope, the possibility of adjustments during construction, and the owners' need for flexibility to make changes during construction.	[7,9]
4	Quality-Related Factors	This includes achieving the highest level of quality overall. Even though quality assurance must be achieved across all delivery methods, some delivery methods assist in accomplishing this goal.	[7,9,10]
5	Owner Organization-Related Factors	The owner's organization significantly impacts the best delivery method choice, including the owner's desired level of control, in-house management experience, and owner's experience.	[7,8,11]
6	Project Characteristics -Related Factors	Sometimes, the project determines the most suitable delivery system, including the project importance, project type, project complexity, project scale, and owner's familiarity with the project.	[7,9]
7	Risk and Relationships-Related Factors	These factors are crucial in choosing the method that fairly distributes risk across contractual parties, including the amount of risk, minimizing adversarial relationships, and minimizing disputes.	[7,11]
8	External Environmental-Related Factors	This includes the economic environment, the number of skilled contractors available in the market, the availability of necessary technologies, rules, and regulations impacts, and the influence degree of national political systems on project delivery systems.	[8,10]

Table 2 Personal Information of Experts.

No.	Place of Work	Years of Experience	Functional Specialization	Academic Degree
1	Ministry of Higher Education & Scientific Research	21	Consultant	Ph.D.
2	Ministry of Higher Education & Scientific Research	18	Academic	Ph.D.
3	Ministry of Higher Education & Scientific Research	16	Consultant	Ph.D.
4	Ministry of Higher Education & Scientific Research	15	Consultant	Ph.D.
5	Ministry of Higher Education & Scientific Research	15	Engineer	Ph.D.
6	Ministry of Construction and Housing	17	Engineer	B.Sc.
7	Ministry of Construction and Housing	13	Engineer	B.Sc.
8	Ministry of Construction and Housing	10	Engineer	M.Sc.

In this research, a methodology combining SWARA with TOPSIS is suggested. SWARA and TOPSIS are MCDM techniques. The first objective of this research is to highlight the factors affecting choosing a project delivery system, and the paper will focus on public sector construction. The second objective is constructing the project delivery system decision method based on the SWARA-TOPSIS theory. The model can well provide a reference for the owner's decision to select the delivery system. Therefore, this research presents the results of a review that examined the factors that affected the PDS selection. This work's main innovation and contribution is that eight categories of factors affecting PDSs selection are identified in the source of a literature review. The present study is the first research to decide on a project delivery system in construction projects using the SWARA-TOPSIS methods. It offers guidance for clients' decision-making on PDS and will serve as a foundation for future decision-making research.

2.MATERIALS AND METHODS

This study was conducted using the following methodology: The first step is a review of the literature to determine the most important factors influencing choosing PDS. This section is followed by using the SWARA technique for determining the relative weights of factors. It uses the Focus Group Discussion Technique (FGDT) with specialists, experts, and decision-makers to rank the factors and make pairwise comparisons. FGD should not exceed six or seven members (eight at maximum). The experts were chosen from engineers, academics, and consultants with long practical and scientific experience in contract and project management. The personal information of the eight experts is shown in Table 2. Finally, the TOPSIS technique was applied to evaluate, rank, and select the proposed project delivery systems to be optimal PDS. Selecting and justifying the final decision are offered. The results support owners' decisions to choose an appropriate PDS objectively and scientifically. Additionally, improving the research techniques employed in the PDS field is possible. The following is a summary of the steps followed:

- **Step 1:** identify and code the factors, as shown in Table 3.

Table 3 Code of Factors Affecting the Decision-Making of Project Delivery Systems.

Code	Categories
F1	Time-Related Factors
F2	Cost-Related Factors
F3	Scope-Related Factors
F4	Quality-Related Factors
F5	Owner Organization-Related Factors
F6	Project Characteristics-Related Factors
F7	Risk and Relationships-Related Factors
F8	External Environmental-Related Factors

- **Step 2:** Determine the factors' weights in a fuzzy environment in a decision-making procedure using the SWARA technique. SWARA is one of the novel methods being used to assess factors' weights. The following are the steps followed in this method [12,13]:
  1. Ranking the factors: Sort the factors from maximum preference to minimum.
  2. Determine the value of (Sj): The process begins with the second factor, where the experts assign the factor j a score between zero and one with respect to the previous factor $(j-1)$. The factor (Cj) is less significant than (Cj-1) [14,15].

$$Sj \leftrightarrow j+1 = \sum_{k=1}^{r} Cj \leftrightarrow j+1/r \qquad \textbf{(1)}$$

Where:
Sj = Importance of the average value
J= 2, 3, 4 ....
Cj= more significant than the previous factor at this time
r= No. of expert

3. Calculate the value of (Kj): The constant (Kj) is calculated as follows:

$$Kj = \begin{cases} 1 & j=1 \\ Sj+1 & j>1 \end{cases} \qquad \textbf{(2)}$$

Where:
Kj= Coefficient of factor
J= 2,3, 4...
Sj+1 = Importance of the average value

4. Determine the value of (qj): The weight qj was recalculated as follows:

$$qj = \begin{cases} 1 & j=1 \\ qj-1/kj & j>0 \end{cases} \qquad \textbf{(3)}$$

Where:
qj= Re-calculated weight
Kj= Coefficient of factor
qj-1= The previous re-calculated weight.

5. Determine the weight of factors:

$$wj = qj/\sum_{k=1}^{m} qj \qquad (4)$$

- **Step 3:** Use the TOPSIS method to classify solutions from limited options, with using TOPSIS. It is feasible to categorize the options using the compromise solution concept. Additionally, it assists the decision-maker in determining the ranking order of the options by generating indicators of compromise based on how far the alternatives are from the ideal solutions, positive and negative. The TOPSIS method can be described as a set of steps for m choices and n factors. For this paper, the alternatives of PDS can be chosen from design-bid-build, construction management, design-build, and turnkey.

The following steps can be followed to implement the TOPSIS Method [16,17]:

- **Step1:** Create a normalized decision matrix: In this stage, multiple attribute dimensions are converted to non-dimensional characteristics that enable comparisons across factors.
- **Step 2:** Create the weighted normalized decision matrix.
- **Step 3:** Calculate the ideal solutions, positive and negative.
- **Step 4:** For each alternative, calculate the separation measures.
- **Step 5:** Determine the relative closeness to the ideal solution [18,19].

3.RESULT AND DISCUSSION

Time-related factors (F1), cost-related factors (F2), scope-related factors (F3), quality-related factors (F4), owner organization-related factors (F5), project characteristics-related factors (F6), risk and relationships-related factors (F7), and external environmental-related factors (F8) are considered the key factors influencing the decision-making process for the project delivery systems and decision to select particular delivery systems in construction projects. The SWARA method was applied to find the weights of factors.

3.1.Ranking the Factors by Expert Survey

All experts rank the factors in the first stage according to their opinions, and the final ranking is created by averaging the expert rankings of the factors. Table 4 shows the factors in descending order by experts. Every expert applies ratings on a scale from 1 to 5, with 5 denoting Very High, 4 denoting High, 3 denoting Medium, 2 denoting Low, and 1 denoting Very Low, to determine their desired level of ratings for each factor.

Table 4 Factors Ranking.

Experts / Factors	Exp. (1)	Exp. (2)	Exp. (3)	Exp. (4)	Exp. (5)	Exp. (6)	Exp. (7)	Exp. (8)	Average	Rank
F1	4	5	4	4	5	5	5	4	4.50	2
F2	5	5	4	5	5	5	4	5	4.75	1
F3	2	3	4	3	2	3	4	2	2.88	6
F4	3	4	5	3	4	4	2	3	3.50	3
F5	3	3	2	3	2	4	2	3	2.75	7
F6	2	3	4	3	3	3	4	3	3.13	5
F7	4	2	3	2	3	5	3	4	3.25	4
F8	1	2	3	3	2	1	3	2	2.13	8

Once experts ranked factors, the results showed that the top-ranking factors were those related to cost, whereas time-related factors were in the second rank, and quality-related factors were in the third rank. While factors related to risk and relationships, owner organization, scope, owner organization, and external environment have a fifth, sixth, seventh, and eighth rank, respectively.

3.2.Weights of Factors (Wj) and Comparative Significance (Sj)

Compared to the first stage, the second stage is similar in many ways. Again, decision-makers conducted their pairwise comparisons to determine the factors' importance order, just as they had in the first stage of the SWARA Method, but this time, instead of averaging the values of weight at the process completion, Eq. (1) was applied to continue the process and average the pairwise comparisons (sj). The process and results are described in Table 5.

Table 5 Assessment of Factors' Relative Importance.

Exp.	RI						
	F1↔F2	F4↔F1	F7↔F4	F6↔F7	F3↔F6	F5↔F3	F8↔F5
Exp. 1	0.4	0.7	0.3	0.3	0.5	0.7	0.4
Exp. 2	0.4	0.9	0.4	0.4	0.5	0.6	0.4
Exp. 3	0.5	0.8	0.5	0.4	0.4	0.8	0.3
Exp. 4	0.4	0.7	0.6	0.5	0.5	0.6	0.4
Exp. 5	0.6	0.6	0.3	0.3	0.3	0.5	0.5
Exp. 6	0.3	0.5	0.2	0.5	0.4	0.6	0.6
Exp. 7	0.3	0.6	0.2	0.4	0.4	0.8	0.3
Exp. 8	0.5	0.5	0.4	0.3	0.5	0.5	0.3
Average value	0.425	0.663	0.363	0.388	0.438	0.638	0.400

3.3.Calculation of the Factors Weights

After concluding the (Sj) comparative between the factors using Eq. (1). The following stage is the factors' weight calculation applying Eqs. (2), (3), and (4). Table 6 shows the factors weighing using the SWARA method.

Table 6 Weights of Factors.

Factors	(Sj j+1)	K j=Sj + 1	qj = qj-1/ kj	Wj = qj / ∑ qj
F2	---	1.000	1.000	0.335
F1	0.425	1.425	0.702	0.235
F4	0.663	1.663	0.422	0.141
F7	0.363	1.363	0.310	0.104
F6	0.388	1.388	0.233	0.078
F3	0.438	1.438	0.155	0.052
F5	0.638	1.638	0.095	0.032
F8	0.400	1.400	0.068	0.023
			SUM= 2.985	SUM= 1.000

3.4.Final Weights of Factors

Table 7 and Fig. 1 show the final findings of the factors' weights calculated using the SWARA method.

Table 7 Final Weights.

No.	Factors	Weights
F2	Cost-Related Factors	33.5 %
F1	Time-Related Factors	23.5 %
F4	Quality-Related Factors	14.1 %
F7	Risk and Relationships-Related Factors	10.4 %
F6	Project Characteristics-Related Factors	7.8 %
F3	Scope-Related Factors	5.2 %
F5	Owner Organization-Related Factors	3.2 %
F8	External Environmental-Related Factors	2.3 %

3.5.Evaluating and Selection PDS by using TOPSIS Technique

In this step, the TOPSIS technique was applied to evaluate, rank, and select the proposed project delivery systems to be the optimal PDS in construction projects, as follows:

3.5.1.Compare All Proposal PDS According to Specified Factors

Evaluating and selecting a decision for each proposed PDS according to the specified factors is collectively represented by a group of experts and specialists in the field of construction management and the questionnaire forms proposed. After calculating the arithmetic mean of all factors represented in the eight experts' opinions for the final decision matrix illustrated in Table 8, the results were obtained. Every expert indicated the qualitative value of each single selected factor by applying a scale for evaluation factors from (10–100), where 100 represents the qualitative assessment Excellence and so for the rest of the values.

Table 8 Final Decision Matrix for Experts.

PDSS / Factors	DBB	CM	DB	TK
Cost-Related Factors	70	80	90	85
Time-Related Factors	60	75	95	90
Quality-Related Factors	85	95	80	75
Risk and Relationships-Related Factors	60	80	90	85
Project Characteristics-Related Factors	65	85	90	85
Scope-Related Factors	90	95	85	80
Owner Organization-Related Factors	70	95	90	95
External Environmental-Related Factors	80	85	85	80

3.5.2.The Normalization Decision Matrix

The results of an expert assessment for each of the advanced proposed projects delivery systems were tabulated according to the factors previously determined. The normalization decision matrix is calculated by applying Eq. (5) to get the normalization decision matrix, as shown in Table 9.

$$rij = Xij \div \sqrt{\sum X^2 ij} \quad (5)$$

Fig. 1 Final Weights

Table 9 Normalization Decision Matrix.

Factors \ PDSS	DBB	CM	DB	TK
Cost-Related Factors	0.429	0.490	0.552	0.521
Time-Related Factors	0.370	0.462	0.585	0.554
Quality-Related Factors	0.505	0.565	0.476	0.446
Risk and Relationships-Related Factors	0.377	0.503	0.566	0.534
Project Characteristics-Related Factors	0.398	0.519	0.550	0.519
Scope-Related Factors	0.513	0.542	0.485	0.456
Owner Organization-Related Factors	0.397	0.539	0.511	0.539
External Environmental-Related Factors	0.485	0.515	0.515	0.485

3.5.3.The Weighted Normalization Decision Matrix

The factors' weights extracted by the SWARA technique were previously clarified and illustrated in Table 7. The weighted normalization decision matrix was calculated using the TOPSIS technique. Thus, combining two techniques simultaneously to arrive at a suitable decision in selecting a project delivery system by applying Eq. (6) to the normalization decision matrix, as shown in Table 10.

$$Vij = Wij * rij \tag{6}$$

Table 10 Weights of Normalization Decision Matrix.

Factors \ PDSS	DBB	CM	DB	TK
Cost-Related Factors	0.144	0.164	0.185	0.175
Time-Related Factors	0.089	0.109	0.137	0.130
Quality-Related Factors	0.071	0.080	0.067	0.063
Risk and Relationships-Related Factors	0.039	0.052	0.059	0.056
Project Characteristics-Related Factors	0.031	0.040	0.043	0.040
Scope-Related Factors	0.023	0.028	0.025	0.024
Owner Organization-Related Factors	0.013	0.017	0.016	0.017
External Environmental-Related Factors	0.011	0.012	0.012	0.011

3.5.4.The Ideal Positive and Negative Solution

The alternative separation from the ideal positive solution was calculated using Eq. (7), and the alternative separation from the ideal negative solution using Eq. (8). The results are shown in Tables 11 and 12.

$$Si^{+} = \sqrt{\sum(Vij - Vj+)\,2} \tag{7}$$

$$Si- = \sqrt{\sum(Vij - Vj-)\,2} \tag{8}$$

Table 11 The Positive Ideal Solution.

Factors \ PDSS	DBB	CM	DB	TK
Cost-Related Factors	0.0012	0.0004	0	0.0001
Time-Related Factors	0.0023	0.0008	0	0.0001
Quality-Related Factors	0.0001	0	0.0002	0.0003
Risk and Relationships-Related Factors	0.0003	0.0001	0	0.00001
Project Characteristics-Related Factors	0.0001	0.00001	0	0.00001
Scope-Related Factors	0.00003	0	0.00001	0.00002
Owner Organization-Related Factors	0.00002	0	0.000001	0
External Environmental-Related Factors	0.000001	0	0	0.000001
∑(Vij-Vj+)2	0.0041	0.0013	0.0002	0.0005
Si⁺= √ ∑(Vij-Vj+)2	0.064	0.036	0.014	0.022

Table 12 The Negative Ideal Solution.

Factors \ PDSS	DBB	CM	DB	TK
Cost-Related Factors	0	0.0004	0.0017	0.0010
Time-Related Factors	0	0.0004	0.0023	0.0017
Quality-Related Factors	0.00006	0.0003	0.00002	0
Risk and Relationships-Related Factors	0	0.0002	0.0004	0.0003
Project Characteristics-Related Factors	0	0.00008	0.00014	0.00008
Scope-Related Factors	0	0.00003	0.000004	0.000001
Owner Organization-Related Factors	0	0.00002	0.000009	0.00002
External Environmental-Related Factors	0	0.000001	0.000001	0
∑(Vij-Vj-)2	0.00006	0.00143	0.00457	0.00310
Si- = √ ∑(Vij-Vj-)2	0.008	0.038	0.068	0.056

3.5.5.The Relative Closeness to the Ideal Solution

Based on the results obtained from the previous steps of applying TOPSIS. The relative closeness to the ideal solution was calculated, and the alternatives were arranged by applying Eq. (9). The results are shown in Table 13 and Fig. 2.

$$Ci = \{Si^{-} / (Si + +Si^{-})\} \tag{9}$$

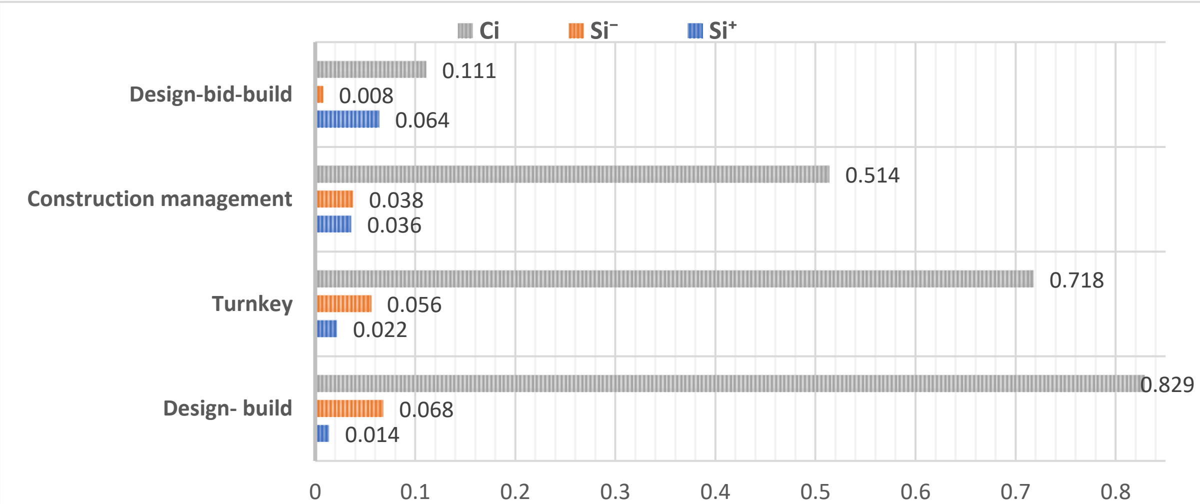

Fig. 2 The Ideal Solution Relative Closeness.

Table 13 The Ideal Solution Relative Closeness.

Ranking	Proposal PDS	Si+	Si-	Ci
1	Design- build	0.014	0.068	0.829
2	Turnkey	0.022	0.056	0.718
3	Construction management	0.036	0.038	0.514
4	Design-bid-build	0.064	0.008	0.111

Based on the results extracted above and through the TOPSIS technique, the design-build is closest to the ideal solution and ranked first among the other suggested project delivery systems.

4.CONCLUSIONS

Even though no project delivery system is perfect, depending on the requirements of a given project, one alternative may be more appropriate than another. Owners have various project delivery options to select from to complete their construction projects and meet their goals. Many factors should be considered to assist the owner in selecting the best delivery method. Based on a literature review, this research identified groups of factors for project delivery systems selection in construction projects. Then, the weight of factors was found by the SWARA technique. The TOPSIS technique was used to rank PDS as a construction project delivery system. The result showed that the design-build was the most proper delivery option, while the turnkey method was confirmed at the second level of significance, Construction management came in at the third level, and Design-bid-build recorded the lowest significance level. However, due to the limitations, only the DBB, DB, CM, and TK delivery methods were studied in this research. Other project delivery systems were not studied, which was additionally a limitation of this research. The research's focus will be expanded in forthcoming studies, and new PDSs can be investigated.

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